

Advanced Fluidics

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Fluidics have evolved significantly in the five decades since pars plana vitrectomy was introduced. Purely mechanical, manual control methods were initially used for both infusion and aspiration. The evolutionary path to advanced fluidics utilizing electronic servo controllers and associated software will be described in this abstract.

Gravity based infusion was used for many years with the VISC, RotoExtractor and Ocutome as well as other systems. Gravity based infusion had no digital readout of infusion pressure and were either “controlled” by manual or motorized adjustment of bottle height relative to the eye. There was no coordination with the aspiration system and response time was exceptionally slow.

Air-over-fluid infusion was introduced on the Alcon Accurus system, it was called gas forced infusion, GFI. This system provided digital readout of infusion pressure in the familiar mmHg but was very slow. Venting was later added to GFI to improve response to pressure commands and called vented gas forced infusion, VGFI. Response time is a critical goal of infusion and especially aspiration systems.

The Alcon Constellation system utilized dual, alternating, small volume, air-over-fluid infusion chambers with air pressure controlled by proportional valves. One chamber provided infusion while the other was filling, fluid level in both chambers was monitored by a vertical array of LEDs and photodiodes. Compensation for pressure drop caused by fluidic resistance in infusion tubing and especially the infusion cannula was addressed by a flow compensation system, During push priming, another advance, a known pressure was applied and actual infusion flow to the atmosphere was sensed by optical Doppler sensor.

The Alcon Unity VCS eliminated air-over-fluid infusion to significantly reduce response time and instead utilizes a virtually non-pulsatile, peristaltic displacement pump with precise, real-time flow sensing via an encoder on the microstepper motor driving the pump. In addition, an eddy current sensor provided real time, very precise, pressure sensing. Real time sensing and control of both infusion pressure and flow provide many advantages.

Aspiration on the Machemer-Parel VISC was controlled by the surgical assistant operating a syringe. Aspiration control by the assistant was not well coordinated with surgeon intent, exceptionally slow because of syringe stiction, etc. and occasionally dangerous.

The O'Malley Ocutome 800 utilized on-off (not proportional, linear) footpedal control and a large air-over fluid aspiration chamber. Foot pedal control by the surgeon was a major advance. The author (Steve Charles) invented proportional (linear) control which was implemented on the Ocutome 8000 and is used on all vitrectomy and phacoemulsification systems.

The Alcon Accurus utilized air-over-fluid aspiration with a smaller chamber than the Ocutome 8000 or subsequent Alcon MVS systems. Faster processors, real time operating system, and switched Ethernet internal network architecture further decreased response time.

The Alcon Constellation utilizes three proportional valves to control pressure/vacuum in the small air-over-fluid aspiration chamber and even faster processor, real time operating system, and switched Ethernet internal network than the Accurus.

Finally, the Alcon Unity VCS eliminated air-over-fluid aspiration and utilizes a virtually non-pulsatile, peristaltic displacement pump with precise, real time flow sensing via an encoder on microstepper motor driving the pump. In addition, an eddy current sensor provides real time, very precise vacuum sensing. Flow control is used for most functions which virtually eliminates flow variation during core vitrectomy and peripheral vitreous shaving. Vitreous is highly anisotropic which results in marked flow variation and movement of

mobile retina when using vacuum control. The Alcon Unity VCS also has a venturi based vacuum control mode best utilized for fluid-air exchange and vitrectomy under air.

Cutting rates have increased from about 400 cuts/minute to 30K cuts/minute over five decades markedly decreasing high frequency, pulsatile vitreoretinal traction. In addition, dual blade, bidirectional, open duty cycle cutters have markedly reduced port-based flow limiting enabling fast response time control by the surgeon.

The military has moved to very flexible, *software defined radio* instead of branch specific VHF, UHF, spread spectrum, or PCM radios. More recently, advanced automobiles have as many as 100 microprocessors, multiple different networks, over 100 sensors and several wireless connectivity solutions. *Software defined vehicles* is rapidly approaching. Real-time sensing of both flow and pressure/vacuum in both infusion and aspiration circuits, time sensitive networking and fast processors and especially elimination of air-over fluid infusion and aspiration and very fast rotary valves (not tubing inch valving) have enabled *software defined fluidics*.